(54) Title: METHOD AND APPARATUS FOR COMPENSATING OPTICAL DISKS FOR EFFECTS OF THIN FILMS
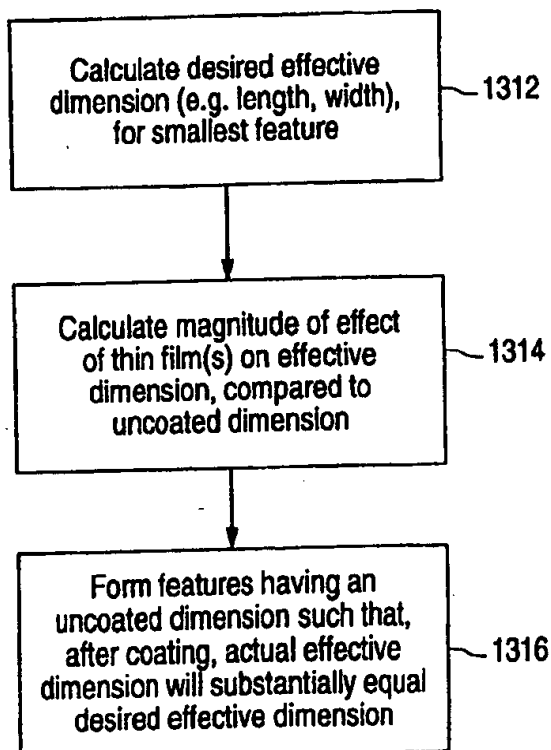
(57) Abstract: An optical data storage/recording medium is provided with a thin film adjacent a data surface. Potential undesired effects of the presence or thickness of the thin film are adjusted for or compensated for to reduce or eliminate the undesired effects. In one aspect, the (uncoated) physical size of data layer features are adjusted so as to produce desired as-detected sizes, shapes or spacings, after a coating or thin film is present. In one aspect, length and/or width of raised features have an uncoated physical size less than the desired as-detected size. In one aspect, depressed features have uncoated physical dimensions greater than desired as-detected dimensions.

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METHOD AND APPARATUS FOR COMPENSATING OPTICAL DISKS FOR EFFECTS OF THIN FILMS

The present invention is directed to a system, method and apparatus to

5   compensate optical disks taking into account an effect of one or more coating films and in

particular to adjusting the size or shape of features in a not-fully-coated pre-disk to

achieve a desired as-detected feature size, spacing or the like.

BACKGROUND INFORMATION

Optical disks for storing information, e.g., in binary form, are provided with a

10   plurality of optical "features", i.e., marks and/or shapes which can be optically detected

and used, e.g., for read and/or write operations. Features may represent content

information, such as information which can be ultimately provided to the user (regardless

of whether the user is a human, a computer or other device), but may also include other

information such as information used for purposes such as focus or tracking (or other

15   servo functions), sector navigation or addressing (or other access operations), testing

purposes, data security purposes, quality control purposes and any of a number of other

purposes, as will be understood by those of skill in the art after understanding the present

disclosure.

Disks with features thereon can be formed using any of a number of processes.

20   One operable process falls generally in the category of injection molding. In injection

molding (of any of a number of objects, including optical disks), a mold cavity having a

size and shape corresponding to (e.g., after thermal shrinking) the size and shape of a

final object, is injected with heated (fluid) thermoplastic material. After cooling e.g., to

the glass transition temperature, the mold is opened and the object is removed.

25   In some situations, features on an optical disk may represent binary digits (bits),

or groups of bits. In most situations, features can be considered to be either in the form of

a protrusion or in the form of a depression. The difference can be most readily described

in the context of a "stamper" (i.e., a device used in a molding device for forming a disk,

the stamper having a generally planar surface and a plurality of protrusions extending

30   from the planar surface into the mold cavity or depressions receding from the planar

surface away from the mold cavity. Protrusions on a stamper provide depressions in the

molded disk and depressions in the stamper provide protrusions in the molded disk.

Features can be formed on one surface of the disk, or on both surfaces (in which case, two opposed stampers are used in the molding device. Although descriptions of a stamper-formed disk are believed useful in describing the difference between protrusion disk features and depression disk features, the present inventions, described below, is not

5   limited to use in disks which are molded, but can be used in disks where features are formed in other fashions (such as by ablation, injection-compression, etching, or other methods).

In typical applications, bits or bit groups are represented by bumps (small protrusions) or pits, (small depressions). Typically, such bumps or pits are positioned

10   along one or more spiral or circular tracks on at least one surface or layer of the disk. Disks may also contain features which do not directly represent data bits. For example, there may be features such as grooves or lands, typically in an extended circular or spiral pattern, e.g., for defining one or more tracks. In some cases, the tracks may have small-scale periodic or other deviations from a circular or spiral pattern (e.g., "wobbled"

15   grooves), such as for tracking and/or timing purposes.

When optical read/write devices include some type of detection of reflectivity (or some other parameter related to reflectivity) as the read/write beam is successively in alignment with lands, bumps, pits, grooves, and the like, typically, reflectivity changes detectably as the beam crosses a leading or trailing edge of a feature. Accordingly, if,

20   e.g., a read/write beam is maintained aligned with a track which bears pits or bumps, a reflectivity transition will ideally be detected near the (track-wise) leading edge and trailing edge of each bump or pit along the track and accordingly, the difference in timing between leading edge and trailing edge transitions in reflectivity are indicative of the (track-wise) length of the bump or pit. In this way, the presence and/or length of a bump

25   or pit can be detected and converted to bits or bit patterns (according to any of a number of encoding schemes).

A number of aspects of the size, shape, distribution or arrangement of features on the disk (and/or of electrical, optical or other parameters associated with their detection) are of significance in the read/write operations. Among these are the as-detected track-

30   wise or radial size of the features, the z-dimension size of the features, the radial spacing of features, the track-wise spacing of features and/or the DC offset of detection signals, particularly for high frequency (short-length) marks compared to relatively longer marks. The design of encoding schemes and design of the read/write device (including size and

shape of the medium, wavelength of the read/write beam and other factors) place constraints on the size and/or shape of features which are desired and/or operable in an optical disk data storage system.

Many previous disk configurations provide a relatively thick, substantially
5   transparent, plastic or other substrate through which the read/write beam passes, before reaching a data layer (i.e., a layer which has readable or writeable features formed or formable thereon). As used herein, "read/write" refers to beams, devices or processes which involve only reading, only writing, or both. In previous typical optical disk configurations, the effective thickness of such substrate (or other relatively thick covering
10   layer) was sufficiently large that the surface of the interface which does not contact the data layer (e.g., the air-substrate interface) was substantially outside the depth-of-field of the optical system used to read or write data, and accordingly, at least some important optical parameters were substantially unaffected (within tolerances required for successful operation of read/write operations) by the presence of the layer (i.e., by the
15   requirement that the read/write beam traverse the substrate before reaching the data layer).

However, it is believed certain limitations on performance arise from the provision of a relatively thick substrate or similar layer. Accordingly, it would be useful to provide a system, method and apparatus which can achieve desired as-detected feature
20   sizes and/or shapes without being limited to relatively thick substrates (or other layers through which the read/write beam must pass before reaching the data layer) for the read/write medium.

SUMMARY OF THE INVENTION

The present invention includes a recognition of the existence, nature and/or source
25   of certain problems, including as described herein.

According to one aspect of the present invention, it is recognized that, in at least some situations, providing a relatively thin film over some or all of an optical disk data layer can affect items such as the "as-detected" size or shape of bumps or pits or other features (e.g., compared to the actual physical size of the feature, e.g., as molded) and
30   that, accordingly, it can be advantageous to correct for and/or account for such effects. As used herein, "as-detected" size, spacing or magnitude refers to whatever feature size, spacing or magnitude is detected by (or indicated by or derivable from electrical or digital signals indicative of beam reflectivity or other feature-indicative parameters) an optical

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disk read/write device (e.g., based on time difference between a beam crossing a leading feature edge and a trailing feature edge, including as described below). In one embodiment, the effect of a thin film is corrected-for by forming features which have an actual, physical, size different from the desired as-detected feature size, e.g., so that after

5   providing the thin film, the as-detected size of the feature (including effects caused by the presence or thickness of the film) is equal to the desired as-detected feature size. The desired as-detected feature size may be the size for any of a number of different features (including bumps, pits, grooves, lands and the like), may be sizes or shapes in any of a number of different dimensions or spacings (including, e.g., track-wise length, radial

10   width, z-dimension magnitude, track-wise distribution, inter-track distances or distributions and the like), and desired as-detected dimensions may be selected to achieve any of the number of different goals (such as providing a minimum, predetermined or type-averaged DC offset, achieving desired mark/space ratio, reducing asymmetry, increasing resolution, decreasing jitter, decreasing cross-talk, increasing signal to noise

15   ratio, and the like, and/or combinations thereof).

Although features of the present invention are believed useful in a number of optical storage contexts, the present invention is believed to be especially useful in the context of a first surface medium, including as described in U.S. Patent Application Serial No. 09/560,781 and/or U.S. Patent Application Serial No. 09/315,398, incorporated

20   herein by reference. In the preferred embodiment, the optical medium is a first-surface medium. Although it may be subject to more than one definition, in one embodiment, the first-surface optical medium refers to a medium in which the read beam during a read operation is incident on or impinges on information content portions of the first-surface optical medium before it impinges on a substrate of the first-surface optical medium. The

25   "information content portions" can be defined as portions of the optical medium that store or contain servo data, address data, clock data, user data, system data, as well as any other information that is provided on the optical medium. The "information content portions" can be integral with the substrate such as the case of a read-only medium. The information content portions can also be separately provided. In such a case, the

30   information content portions can be, for example, an information layer of a writeable medium.

In one additional or alternative definition, the first-surface optical medium can refer to an optical medium having a tangible thickness in which a read light beam during

a read operation traverses less than 100 micrometers of this thickness before impinging on the information content portions.

In at least some approaches, a first surface medium may be formed by a process which includes molding in a molder device 1812 (Fig. 18) such as an injection-molding

5   device, to form a pre-disk having features formed on at least a portion of a surface, (including by a process generally as described in U.S. Application Serial No. 09/652,975, filed August 31, 2000, optionally providing a metallic or other reflective material, and forming a thin film using a coater 1814 (e.g., by a sputtering process, electron beam process, spin coating, an ion deposition process, electro-deposition process or the like)

10 substantially over the data layer or surface. Those of skill in the art, at least after understanding the present disclosure, will understand appropriate injection molding or other pre-form forming apparatus and will understand appropriate sputtering apparatus or other apparatus for coating with one or more thin films. The film is preferably sufficiently thin that a substantially first-surface medium is the result. Typically, such a

15 thin film will be less than about 200 nanometers thick (i.e., in the z-dimension), more preferably less than about 130 nanometers thick and even more preferably less than about 100 nanometers thick. In one embodiment, the film serves the function of at least partially enhancing contrast or bit-detectability. However, many type of thin films can be provided including protective films, anti-reflective films and the like. In one embodiment

20 a dielectric film, formed substantially of SiO_xN_y (silicon oxynitride) is provided.

As noted above, in typical previous devices where the read/write beam travels through a relatively thick substrate (such as about 100 micrometers or more) before reaching a data layer, the presence or thickness of the relatively thick substrate was considered to have little effect on certain parameters such as-detected feature sizes, DC

25 offset, signal to noise ratio and the like. However, it has been found that thin films can have an effect on the as-detected feature size, signal to noise ratio and/or DC offset and the like, which can be significant for at least some optical storage systems (i.e., can affect efficiency, reliability and similar aspects of the system), especially for first surface media. Accordingly, in one aspect of the invention, the physical size or shape of features, or their

30 spacing or arrangement on a data layer is adjusted to compensate for, or take into account, the effect of a thin film. In one embodiment, e.g., when a feature involves a pit or depression, with respect to the land region, a track-wise (longitudinal) dimension of

the feature is increased, preferably by an amount about equal to twice the projection of a feature side wall film thickness on the data plane. In another embodiment, particularly useful for features which project outwardly or upwardly (i.e., in the z-dimension) with respect to the data surface, the physical feature size is made smaller than the desired as-

5   detected size, so as to at least partially account for the presence of and/or thickness of, the thin film, such as being decreased by an amount equal to about twice the projection of the feature sidewall film thickness on the data plane.

In some approaches, adjustment, for compensating for or accounting for the effects of a thin film, can be achieved empirically, such as by adjusting feature sizes and

10   testing the results, in an iterative fashion until desired results (or ranges of results) are achieved (such as desired data discrimination, desired signal to noise ratio and/or desired DC offset is obtained).

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a top perspective view of a data disk of a type that can be used in

15   accordance with an embodiment of the present invention;

Fig. 2 is a partial perspective view of an uncoated surface of a data disk having pits formed on adjacent tracks;

Fig. 3 is a partial perspective view of an uncoated surface of a data disk having bumps formed on adjacent tracks;

20   Fig. 4 is a partial perspective view of an uncoated surface of a data disk having lands formed on adjacent tracks;

Fig. 5 is a partial perspective view of an uncoated surface of a data disk having grooves formed on adjacent tracks;

Fig. 6 is a cross-sectional view taken along line 6-6 of Fig. 2, but after a thin film

25   has been applied thereto;

Fig. 7 is a cross-sectional view taken along line 7-7 of Fig. 6, but after a thin film has been applied thereto;

Fig. 8 is a cross-sectional view taken along line 8-8 of Fig. 3 but after a thin film has been applied thereto;

30   Fig. 9 is a cross-sectional view taken along line 9-9 of Fig. 8

Fig. 10 is a radial cross section taken along line 10-10 of Fig. 4, but after a thin film has been applied thereto:

Fig. 11 is a cross-sectional view taken along line 11-11 of Fig. 5, but after a thin film has been applied thereto;

Fig. 12 is a cross-sectional view similar to the view of Fig. 8, but with multiple thin films applied;

5   Fig. 13 is a flowchart illustrating a process according to one embodiment of the present invention:

Fig. 14A is an illustration of a reflectance signal from a series of features in the absence of substantial compensation;

Fig. 14B is an illustration similar to that of Fig. 14A, but showing a reflectance
10   signal from a disk formed using compensation according to an embodiment of the present invention;

Fig. 14C illustrates a binary output provided in using the reflectance signal from Fig. 14B, according to an embodiment of the present invention;

Fig. 15 is a cross section similar to Fig. 8, but with sidewall coatings reduced or
15   eliminated;

Fig. 16 is a block diagram of a read channel, usable in accordance with embodiments of the present invention;

Fig. 17A is a graph of asymmetry as a function of as-detected bump length, Fig. 17B illustrates the growth of bumps due to the addition of films; and

20   Fig. 18 is a block diagram depicting apparatus that can be used for fabricating disks according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in Fig. 1, an optical disk 112 has at least one major surface 114 having one or more circular 116 or spiral tracks defined thereon by the position of pits, bumps,
25   lands, grooves or other features. Directions or positions on or with respect to the optical disk 112 can be discussed with reference to a radial axis 118, a z-axis 122 (which is perpendicular to the surface or plane 114 of the disk 112) and a track-wise dimension or direction 124. In the illustration of Fig. 2, a portion of a data layer or surface 212 has a plurality of pits or depressions; 214a, b, c, d formed therein, positioned on adjacent tracks
30   216a, b. Similarly in Fig. 3, a plurality of raised features or bumps 314a, b, c, d positioned along adjacent tracks 316a, b project above the major surface or the land surface 315 of a data layer 312. Fig. 4 illustrates raised lands projecting in the z-direction (outwardly or upwardly) from a surface 415 of a data layer 412 defining first and second

tracks 416a, b and Fig. 5 illustrates first and second grooves projecting in the z-direction (inwardly or downwardly) with respect to the major surface 515 of a data layer 512. Although figures 4, 5, 10 and 11 depict lands and grooves with substantially vertical sidewalls, in practice, sidewalls for lands and grooves will typically have an angle or

5   slope, (e.g., between about 30° and about 60°).

Figs. 2-5 depict a data layer without a film or coating placed thereon. As seen from Figs. 2-5, the size, shape and position of the features and tracks define a number of physical features or spacings of the features or tracks. The features 214b; 314b; 414a,b; 514a,b can each be defined as having a radial width 222, 322, 422, 522 a z-dimension

10   magnitude (i.e., a depth 224, 524 in the case of a pit or groove or a height 324, 424 in the case of a bump or land) inter-track spacing 226, 326, 426, 526 and, for features such as pits and bumps, a (track-wise) length 228, 328, and the like. Some or all features of the present embodiment can be used in connection with a variety of sizes and shapes of optical disk features. In one particular embodiment, features typically have a z-

15   dimension magnitude 224 of about 80 nanometers or more, a radial dimension magnitude 222, 322, 422, 522 of about 230 nanometers or more, a length 228, 328, 428, 528 between about 300 nanometers and about 2000 nanometers, inter-feature spacing (track-wise) 232, 332 of about 300 - 2000 nm, track pitch (center-to-center distance between adjacent tracks) of about 740 nm, and track-to-track (or inter-track) spacing (between

20   adjacent edges of adjacent tracks) 226, 326, 426, 526 of at least about 300 nm, typically at least about 400 nm for a read-only area or disk. In at least some optical storage approaches, all of the pits 214a,b,c,d and/or all of the bumps 314a,b,c,d will have substantially similar widths 222, 322, but may differ substantially in the track-wise dimension or length 228, 328. In these systems, there will at least be a plurality of

25   relatively short (track wise) pits or bumps (or other features) and a plurality of relatively longer pits or bumps (or other features) and typically the read/write system must be capable of detecting (and preferably distinguishing between) the short (track-wise) and long (track-wise) features.

Figs. 6-11 depict cross sections through various feature-bearing portions of data

30   layers after a thin film 612, 812, 1012, 1112 has been provided. The data layer 212, 312, 412, 512 can be formed or provided in a number of fashions. In one embodiment, the data layer is formed by injection molding a polycarbonate or similar substance using a form having members (e.g., "stampers") which define the features, generally as described

in co-pending Application Serial No. 09/652,975, filed August 31, 2000, entitled Double-Sided Digital Optical Disk and Method incorporated by reference. Other possible procedures for forming data layers can include injection/compression formation (as is used, e.g., in compact disk (CD) fabrication), stamping (as was used in vinyl audio

5   recording formation) and the like. The data layer may be formed directly of a material having desired reflectivity or other optical properties, or may have a metal alloy or other material placed thereon (not shown in the illustrations), (e.g., for providing the reflective surface on which the read/write beam is substantially focused).

The thin film 612, 812, 1012, 1112 has (on horizontal surfaces) a z-dimension

10   magnitude or thickness 614, 814, 1014, 1114 sufficiently small that the structure operates substantially as first surface optical medium (e.g., as described above). In one embodiment, the thickness 614, 814, 1014, 1114 (or, if multiple layers 1212a,b,c are provided, e.g., as depicted in Fig. 12, the combined thickness 1214) is less than about 200 nanometers, preferably less than about 130 nanometers and even more preferably less

15   than about 100 nanometers.

As illustrated in Figs. 6-11, the thin films 612, 812, 1012, 1112, 1212 define an upper surface 616, 816, 1016 which has a size, shape or geometry differing somewhat from the underlying features. For example, as shown in Fig. 6, although the pit 214d defined in the data layer 212 has a first length 228, the length of the pit as defined by the

20   upper surface 616 of the film 612 has a somewhat shorter length 628. Similarly, the length 828 of the feature defined by the upper surface 416 of the bump 314d as illustrated in Fig. 8 is somewhat greater than the length 328 defined by the underlying feature 314d. A pit width 722 defined by the film upper surface 616 is somewhat smaller than the pit width 222 defined by the data layer 212 (Fig. 7) and the bump width 922 defined by the

25   upper surface 816 of the coating or film is somewhat larger than the bump width 322 defined by the data layer 312. This relationship occurs regardless of whether the feature length and width is measured at the land level 228, 628, 222, 722, 328, 828, 322, 922, at the bottom of the feature (in the case of pits) 228', 628', 222', 722', at the tops of the features (in the case of bumps) 828', 328', 922', 322' or some other intermediate position.

30   As illustrated in Fig. 10, in the case of lands 414a, 414b the width 1022 defined by the upper surface 1016 of the film is somewhat greater than the width 422 of the underlying land 414a formed in the data layer. In the case of grooves, the width 1122 defined by the

upper surface of the filing is somewhat less than' the width 522 of the groove 514a
formed in the data layer 512.

It has been found that, in at least some optical disk configurations, even though
the thin film is formed of a material which is substantially transparent to the optical
5   read/write beam, and even though film thickness is typically less than a wavelength, the
presence and/or thickness of the film 612, 812, 1012, 1112 can affect optical detection
parameters with respect to the detection or sensing of features. Without wishing to be
bound by any theory, it is believed that, for at least some optical or detection parameters,
the system behaves as though the shape and size or spacing of the feature of the recording
10   layer is modified to correspond to the shape, size or spacing of the upper surface 614,
814, 1014, 1114 of the thin film. For example, if a system is intended to detect a change
of reflectivity both when the leading edge 234 of a pit 214d and the trailing edge 236 pass
beneath a read/write beam (not shown) e.g., as the disk 114 rotates while the beam is
positioned along track 216b, it has been found that, in at least some situations rather than
15   detecting the leading 234 and trailing 236 edges of the pit 214d defined in the data layer
212, the system will define the transition at the leading and trailing edges 634, 636
defined by the upper surface 616 of the thin film 612 (Fig. 6). For this reason, in these
situations the system will detect a length 628 ("as-detected length") 628 which is shorter
than the actual physical length 228 of the pit 214d formed in the data layer 212.
20   Similarly, transitions in a reflectance signal or similar signal caused by radial movement
will result in a signal reflecting an as-detected width 722 which is less than the actual
physical width 222 of the pit 214d (Fig. 7).

In the case of a bump, the as-detected length 828 is greater than the physical
length 328 (Fig. 8) and the as-detected width 922 is greater than the physical width 322.
25   Similarly, the as-detected land width 1022 (Fig. 10) will be greater than the actual
physical land width 422 and the as-detected groove width 1122 (Fig. 11) will be less than
the physical groove width 522. It is noted, however, that there is substantially no
difference, for most purposes, between the as-detected z-dimension magnitude of features
624, 824, 1024, 1124 and the corresponding physical z-dimension of features 224, 324,
30   424, 524.

Without wishing to be bound by any theory, it is believed that the existence and/or
significance of, such effects of thin films on optical data recording and/or the need for,
and techniques for, compensating or addressing these effects, has generally been

previously unrecognized or unappreciated, at least partially because the effects are
somewhat counter-intuitive given the transparent and sub-wavelength nature of the thin
films and partially because there has been little, if any, previous effort to provide a
practical first surface optical recording system, especially in a small format.

5   There are a number of potential undesirable consequences of these (or other)
effects caused by the presence or thickness of a thin film. One undesirable consequence
is illustrated by Fig. 14A which is a graph showing (on the vertical axis) a reflectivity
signal 1412 through time (on the horizontal axis) as a read beam is successively aligned
with two (track-wise) long depressed features 1414a, five (track-wise) short depressed
10   features 1414b and of along depressed feature 1414c. In at least one embodiment,
leading and trailing edges of features are presumed to occur when the reflectivity signal
1412 crosses (either increasing or decreasing) a predetermined reflectivity level.
Typically and preferably, the predetermined level is taken as a level midway between a
normal maximum reflectivity signal 1416 and a minimum signal 1418 for long features
15   1414a. This midway level 1422 sometimes referred to as a DC offset value. As seen in
Fig. 14A, it has been found that, in the absence of taking into account the effect of a thin
film, the reflectivity signal in the region of (track-wise) short depressed features 1414b
remains relatively high and never crosses a mid-value DC offset level 1422. An effect
similar to that illustrated in Fig. 14A is also found for raised features; but in that case, the
20   signal for short raised features remains relatively low, but similarly may never cross the
mid-level DC offset level 1422. Accordingly, in the situation depicted in Fig. 14A, in
order to detect short depressed features 1414b, it would be necessary to use a DC offset
value 1424 which substantially departs from the desired mid level value 1422. When a
DC offset or threshold value is set relatively far from a mid level value, there tends to be
25   an undesirable amount of distortion, and the system can be unacceptably sensitive to
variations in bit lengths. Fig. 14B illustrates a corresponding situation but in which the
effect of the thin film has been accounted for (e.g., as described below). In this situation,
a region having (track-wise) short depressed features 1426 has reflectivity changes which
are substantially centered around the mid level DC offset 1422. Fig. 14C illustrates a
30   digital (binary) output which can be obtained from triggering rising and failing edges of
pulses by increasing and decreasing crossings (respectively) of the DC offset value 1422.
           The value of asymmetry can be useful to evaluate DC offset. Asymmetry is a
measure of the relative DC levels of the short versus long marks and can be expressed in

units of percent of large mark peak-to-peak amplitude. For a "slicing channel," it is desirable to have asymmetry as close as possible to zero. With reference to Fig. 16, the slicer component 1612 compares an analog signal 1614 (which indicates, e.g., reflectivity of the read beam), processed by an equalizer 1616, to a reference slicing level which is

5   the result of providing a digital interrogator signal from an interrogator 1618 through a digital-to-analog converter 1622. The slicer 1612 provides a digital output signal 1624 every time there is a transition of the analog signal 1614, (i.e., a crossing of the reference level or threshold level). A phase measure cell 1626 detects any transition from the slicer 1612. For each slicer edge, the phase measure cell 1626 generates an "event" and a

10   "polarity" signal. The event signal stays high for one clock cycle to indicate that a transition has been detected in the clock window. The "polarity" signal transitions high if the transition was an increasing or rising edge, and transitions low if the signal was a falling edge. If asymmetry deviates from zero, the transitions will tend to move further from the center of the clock window, decreasing the likelihood of the transition being

15   detected in the desired location.

Fig. 17A illustrates theoretically calculated asymmetry for 300 nanometer-width features (1712b) and 435 nanometer-wide features (1712a), and experimentally-obtained data points 1714, with asymmetry (percentage) shown on the vertical axis and as-detected feature length (in nanometers) shown on the horizontal axis, for a bump height of about

20   80 nanometers, bump length of about 300 nm, bump width of about 230 nanometers, and a sidewall angle of about 45° (uncoated dimensions of the features). As seen in Fig. 17A, for at least some as-detected bump lengths, there can be substantial departures from zero percent asymmetry.

There are a number of ways in which the effect of a thin film can be taken into

25   account so as to avoid some or all potential disadvantages arising from thin film effects. In the approach illustrated in Fig. 13, the as-detected dimension(s) (e.g., track-wise length, feature width and the like) desired for various features is calculated 1312. As will be understood by those of skill in the art, at least after understanding the present disclosure, the dimensions which are desired may be affected by a number of factors

30   including the encoding scheme which is used, the wavelength of the read/write beam, data density and the like. In one embodiment, the optical disk is configured for use in connection with a read/write device having a read/write beam wavelength of about 650 nanometers and a numerical aperture of about 0.6. Optical disks, and read/write devices

therefore, can be provided generally in accordance, (e.g., with those described in the patent applications which are incorporated by reference, supra). In one example, it is possible to calculate dimensions of the smallest feature so as to achieve a desirable and effective DC offset value, (e.g., as illustrated in Fig. 14B) (as opposed to feature

5   dimensions which would tend to bring about the undesirable situation illustrated in Fig. 14A). This represents the desired as-detected feature size. This determination can be made on a theoretical or modeling basis, or can be determined empirically (such as testing various bit lengths on an uncoated optical disk to determine the bit size at which there is a significant departure from the desired situation as depicted in Fig. 14B).

10   The magnitude of the effect of thin films on as-detected (as opposed to physical) feature dimensions is determined or calculated 1314. In one approach, the magnitude is taken as being substantially equal to the projection, onto a plane parallel to the major surface of the data layer, of the film thickness 652 as it occurs on the side wall of a feature. For example, when the side wall is at an angle 654 of about 45°, the magnitude

15   of the projection of the thickness 656 on a plane parallel to a major surface of the disk 114 is equal to the film thickness 652 (which can, in many cases, be taken to the equal to the vertical thickness 614) times an "angle factor" of $2^{-\frac{1}{2}}$. Because, in general, there will be an effect on two opposing side walls of a feature, the total effect will be twice this value. Thus, in one embodiment, for a bump, the magnitude of the effect is estimated

20   such that the as-detected length (e.g., 828 in Fig. 8) is equal to the feature physical length 328 plus the correction value noted above, or

$$L_{828} = L_{328} + (2/\sqrt{2})\, D_{814} \tag{1}$$

where L_{828} is the as-detected bump (track-wise) length,

L_{328} is the physical bump length (i.e., in the absence of coating) and

25   D_{814} is the film thickness.

As illustrated in Figs. 10 and 11, when the angle 1054 is 90°, the projection of the thickness 1056 is substantially equal to the layer thickness 1014 (i.e., the "angle factor" is equal to 1) so that, in the example of Fig. 10, the magnitude of the effect of the thin film can be expressed as

30       $$L_{1022} = L_{422} + 2\, D_{1014} \tag{2}$$

Where L_{1022} is the as-detected feature width,

L_{422} is the physical feature width and

D_{1014} is the thin film thickness.

Those of skill in the art will understand how to calculate estimated correction formulas for other angles.

Once the magnitude of the effect is determined (e.g., by theoretical computation, modeling, or by empirical studies), it is then possible to proceed with forming disk pre-

5   forms (i.e., the form of the disk before the thin film or films are applied) in such a way as to take into account and/or compensate for the effects of the thin film. For example, in the configuration of Fig. 8, solving equation (1) for the physical length, it is found that, in order to achieve the desired result, the physical length of the feature should be less than the desired as-detected length. In particular, the physical length can be estimated as:

10    $$L_{328} = L_{828} - (2/\sqrt{2}) D_{814} \qquad\qquad (3)$$

As one example, when it is desired to have an as-detected bump length, with 45° sidewalls which is no larger than about 435 nanometers, the disk pre-form must be formed with bump features having a length of about 300 nanometers (for a sidewall film thickness of about 75 nanometers).

15   As can be seen from comparing Figs. 6 and 7 with Figs. 8 and 9, and comparing Fig. 10 with Fig. 11, features such as bumps 314 and lands 414a, b which extend upwardly (with reference to the view of Fig. 1) along the z-axis 122 (in a direction towards the direction from which the read/write beam will arrive) can be compensated by making the (uncoated) physical feature dimension smaller than the desired as-detected

20   dimension. In contrast, features such as pits 214d or grooves 514a,b which project downwardly (along the z-axis, (i.e., in a direction away from the direction from which the read/write beam will arrive) can be formed with physical features which are larger than the desired as-detected dimensions.

Preferably, the system is used to account for or compensate for other dimensions

25   or spacings which may be affected by the presence or thickness of a thin film. For example, it is desired, in general, to provide relatively small track pitch in order to achieve relatively high data density. However, the inter-track spacing 226, 236, 426, 526 must be sufficiently large to avoid an undesired amount of track-to-track cross talk. As can be seen from Fig. 10, for inter-track distances calculated with respect to raised

30   features, the effect of a thin film is to decrease the as-detected inter-track distance 1026, compared with the physical inter-track distance 426. Note that this is the opposite of the effect of the thin film on the width of raised features (which have an as-detected width 1022 greater than the physical width 422). Accordingly, in one embodiment, the effect of

the thin film is accounted for or compensated for by decreasing the width of the raised physical feature but increasing the inter-track spacing of the raised physical features, in order to achieve desired as-detected width and desired as-detected inter-track spacing.

With respect to depressed features, as depicted in Fig. 11, the effect of the thin

5   film is to provide an as-detected inter-track spacing 1126 which is greater than the physical inter-track spacing 526 and, accordingly, in one embodiment, for tracks defined by grooves or other depressed features, the physical inter-track distance is reduced (compared to the desired as-detected inter-track distance) in order to compensate for the effect of a thin film.

10   As shown in Fig. 12, when multiple thin films are present 1212a, 1212b, 1212c, it is possible, according to an embodiment of the present invention, to adjust the one or more physical dimensions such as a feature physical length 328 by a factor which takes into account the total thickness of the multiple films 1214, in order to achieve a desired as-detected length 1228.

15   As will be understood by those of skill in the art after understanding the present disclosure, there are other ways in which the effect of a thin film can be accounted for. For example, it is possible to provide embodiments in which the thin film is provided in such a manner that it has a desired thickness on horizontal surfaces 1512 (Fig. 15) but has little or no thickness positioned on feature side walls 1514. For example, this structure

20   may be achieved by an ion deposition process on 90° sidewall structures.

In another embodiment, the effect of the presence or thickness of a thin film can be to provide a separately-molded thin cover layer, having features molded into it, which is glued or otherwise coupled to a substrate.

In general, injection molding equipment, materials and processes (or other

25   equipment, materials and processes for forming disks or disk pre-forms) are selected or adjusted in accordance with, among other parameters, the size and shape of the features to be replicated. Accordingly, if, e.g., an injection molding process is used to provide features which have been reduced or increased in size (in order to compensate for the effects of a thin film) it may be necessary to adjust or modify injection molding

30   parameters (such as pressures, temperatures, hold times and the like) in order to achieve the desired feature size. Some aspects of relationships between features, sizes, and injection molding parameters are discussed in U.S. Application Serial No. 09/652,975, filed August 31, 2000, incorporated herein by reference.

In light of the above description, a number of advantages of the present invention can be seen. The present invention makes it feasible to provide a medium such as an optical disk, preferably a first surface medium, with one or more thin films while still achieving desirable or acceptable levels of signal to noise ratio, mark/space ratio,

5   asymmetry, resolution, jitter, DC offset and the like. The present invention provides a basis for obtaining theoretical or modeling estimates of adjustments which can be useful for avoiding undesired consequences of the presence or thickness of a thin film. In one aspect, effects of a thin film are adjusted for or compensated for, at least partially using an empirical or iterative process. In one aspect, the present invention provides guidance

10   for conducting an effective and efficient empirical or iterative adjustment process (such as recognizing the different effects on raised verses depressed features and/or on feature dimensions verses inter-track dimensions). The present invention makes it possible to provide effective optical storage devices or media containing one or more thin films, preferably in the context of first surface media, with desirable data integrity, and ease of

15   use.

A number of variations and modifications of the invention can be used. It is possible to use some aspects of the invention without using others. For example, it is possible, but not necessarily desirable, to correct feature lengths without correcting feature widths or inter-track spacings. Although, the present invention was described in

20   the contest of an optical disk. It is also possible to use some or all aspects of the present invention in connection with other optical storage media including plates, films, drums, and three-dimensional media such as three-dimensional holographic blocks. Although examples have been described above in relation to first surface media, it is also possible to use some or all aspects of the present invention in other variations or embodiments

25   such as double-sided disks, disks with multiple stacked data layers, disks which are read or written using any of a plurality of light wavelengths, such as blue light, ultraviolet, infrared and the like, devices using read/write beams which are non-laser light and the like.

The present invention, in various embodiments, includes components, methods,
30   processes, systems and/or apparatus substantially as depicted and described herein, including various embodiments, subcombinations, and subsets thereof. Those of skill in the art will understand how to make and use the present invention after understanding the present disclosure. The present invention, in various embodiments, includes providing

devices and processes in the absence of items not depicted and/or described herein or in various embodiments hereof, including in the absence of such items as may have been used in previous devices or processes, (e.g., for improving performance, achieving ease and/or reducing cost of implementation). The present invention includes items which are

5   novel, and terminology adapted from previous and/or analogous technologies, for convenience in describing novel items or processes, do not necessarily retain all aspects of conventional usage of such terminology.

The foregoing discussion of the invention has been presented for purposes of illustration and description. The foregoing is not intended to limit the invention to the

10 form or forms disclosed herein. Although the description of the invention has included description of one or more embodiments and certain variations and modifications, other variations and modifications are within the scope of the invention, (e.g., as may be within the skill and knowledge of those in the art, after understanding the present disclosure). It is intended to obtain rights which include alternative embodiments to the extent

15 permitted, including alternate, interchangeable and/or equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

WHAT IS CLAIMED IS:

1.   A method for producing an optical disk comprising:

determining a first lateral magnitude which is desired for at least one feature on the optical disk;

5   providing a stamper having a plurality of stamper features formed therein, including at least a first stamper feature, said first stamper feature having a lateral magnitude different from said first lateral magnitude;

using said stamper to form an optical disk pre-form, having a plurality of disk features corresponding to said stamper features, said plurality of disk features including a

10   first disk feature corresponding to said first stamper feature; and

providing at least a first thin film on at least a portion of said disk pre-form, said portion including at least said first disk feature, wherein said first disk feature, after coating, has an as-detected lateral magnitude about equal to said first lateral magnitude.

2.   A method, as claimed in Claim 1, wherein said plurality of disk futures includes

15   one or more features selected from the group consisting of a bump, a pit, a groove and a land.

3.   A method, as claimed in Claim 1, wherein said step of providing at least a first thin film coating provides a first-surface optical disk.

4.   A method, as claimed in Claim 1, wherein said first lateral magnitude is less than

20   about 450 nanometers.

5.   A method, as claimed in Claim 1, wherein said first lateral magnitude is less than about 250 nanometers.

6.   A method, as claimed in Claim 5, wherein said disk further includes at least one feature with a lateral dimension of at least about 2 micrometers.

25   7.   A method as claimed in Claim 1, wherein said thin film has a thickness less than about 200 nanometers.

8.   A method as claimed in Claim 1, wherein said thin film has a thickness less than about 100 nanometers.

9.   A method as claimed in Claim 1, wherein said thin film has a thickness less than about 50 nanometers.

5   10.   A method as claimed in Claim 1, wherein said first stamper feature has a lateral magnitude different from said first lateral magnitude by an amount less than or equal to about a thickness of said first thin film.

11.   A method for producing an optical disk comprising:

determining a desired as-detected size related to one or more features on the

10   optical disk;

determining a compensation magnitude substantially equal to the magnitude of an effect of a thin film on an as-detected feature size;

molding a disk preform having at least a first feature with a physical size which differs from said desired as-detected size by an amount about equal to said compensation

15   magnitude;

coating at least a portion of said disk preform with at least a first thin film, said portion including at least said disk feature, wherein said first disk feature, after coating, has an as-detected size about equal to said desired as-detected size.

12.   A method as claimed in Claim 11, wherein said disk feature is selected from the

20   group consisting of a bump, a pit, a groove and a land.

13.   A method as claimed in Claim 11, wherein said step of coating provides a first surface optical disk.

14.   A method as claimed in Claim 11, wherein said desired as-detected size is less than about 450 nanometers.

25   15.   A method as claimed in Claim 11, wherein said thin film has a thickness less than about 200 nanometers.

16.   A method as claimed in Claim 11, wherein said thin film has a thickness less than about 100 nanometers.

17.   A method as claimed in Claim 11, wherein said thin film has a thickness less than about 50 nanometers.

5   18.   An optical disk which is formed by a process comprising:

determining a desired as-detected size related to one or more features on the optical diskE;

determining a compensation magnitude substantially equal to a magnitude of an effect of a thin film on an as-detected future size;

10   molding a disk preform having at least a first feature with a physical size which differs from said desired as-detected size by an amount about equal to said compensation magnitude;

coating at least a portion of said disk preform with at least a first thin film, said portion including at least said disk future, wherein said first disk feature, after coating,

15   has an as-detected size about equal to said desired as-detected size.

19.   An optical disk fabrication system for fabricating an optical disk with a desired as-detected size related to one or more features on the optical disk comprising:

means for molding a disk preform having at least a first feature with a physical size which differs from said desired as-detected size by an amount about equal to a

20   magnitude of an effect of a thin film on an as-detected feature size; and

means for coating at least a portion of said disk preform with at least a first thin film, said portion including at least said disk feature, wherein said first disk feature, after coating, has an as-detected size about equal to said desired as-detected size.

20.   A system as claimed in claim 19 wherein said means for molding includes at least

25   one device selected from the group consisting of:

an injection molder; and

an injection/compression molder.

21.   A system, as claimed in Claim 19, wherein said means for molding further comprises an automatic control system configured to adjust at least a first molding parameter in such a fashion as to reliably replicate features having said physical size.

22.   A system, as claimed in Claim 21, wherein said automatic control means comprises at least a first programmed computer.

23.   A system, as claimed in Claim 21, wherein said first molding parameter is selected from the group consisting of an injection temperature, an injection pressure or a hold time.

24.   A system, as claimed in "Claim 19, wherein said means for coating is selected from the group consisting of a sputterer, a spin coater, or an ion deposition coater.

25.   A method, as claimed in Claim 19, wherein said disk feature is selected from the group consisting of a bump, a pit, a groove and a land.

26.   A method, as claimed in Claim 19, wherein said step of coating provides a first surface optical disk.

27.   A method, as claimed in Claim 19, wherein said desired as-detected magnitude is less than about 450 nanometers.

28.   A method, as claimed in Claim 19, wherein said thin film has a thickness less than about 200 nanometers.

29.   A method, as claimed in Claim 19, wherein said thin film has a thickness less than about 100 nanometers.

30.   A method, as claimed in Claim 19, wherein said thin film has a thickness less than about 50 nanometers.

1/7
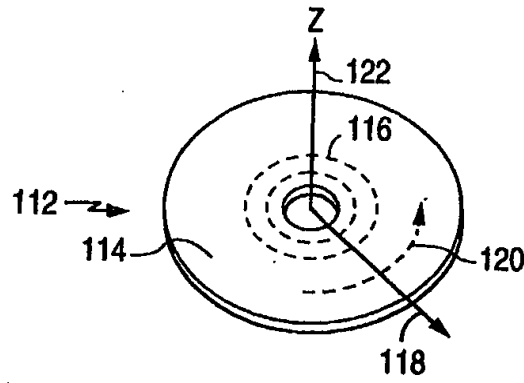
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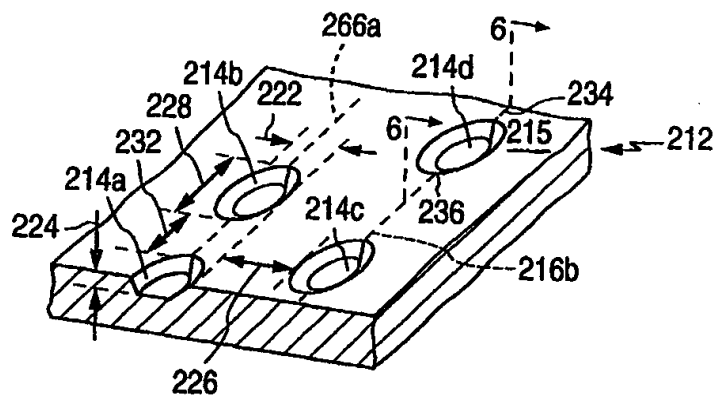
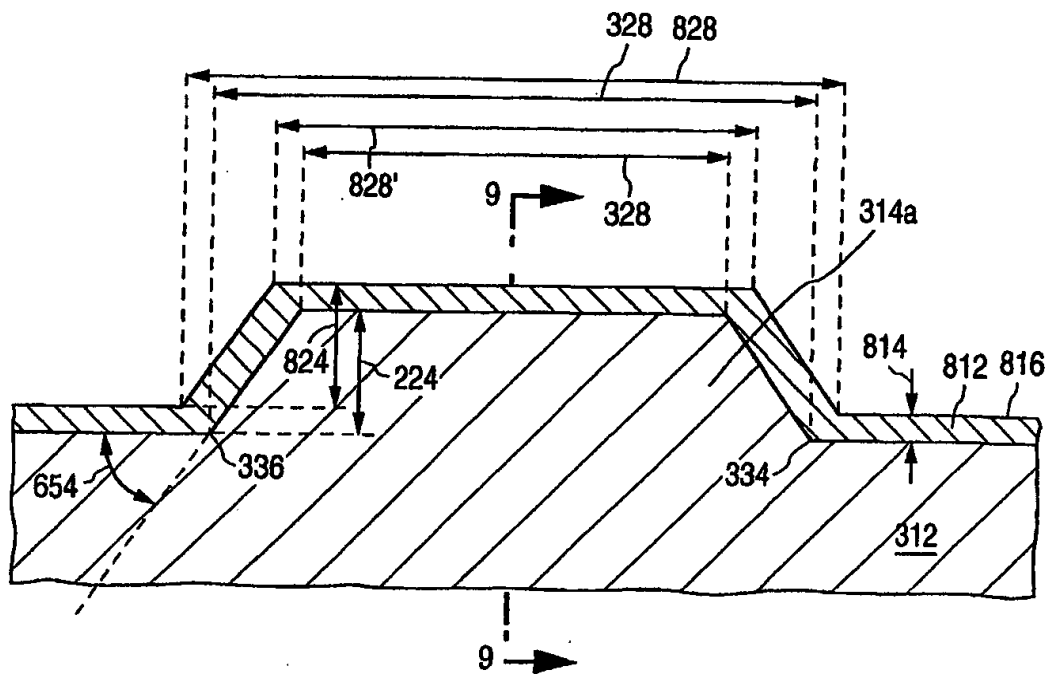**Fig. 2**
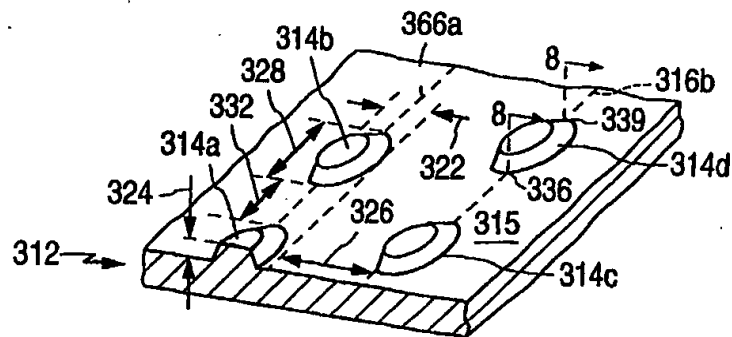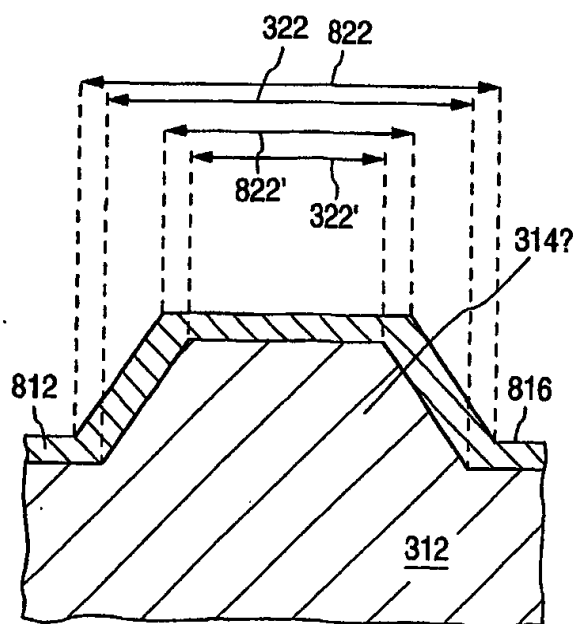

Fig. 3

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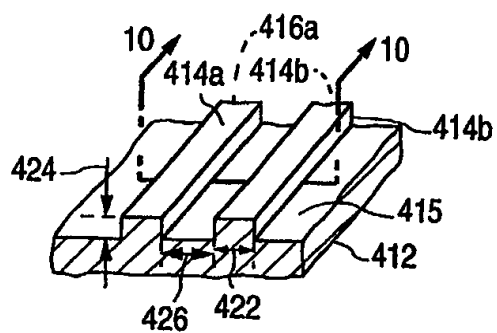
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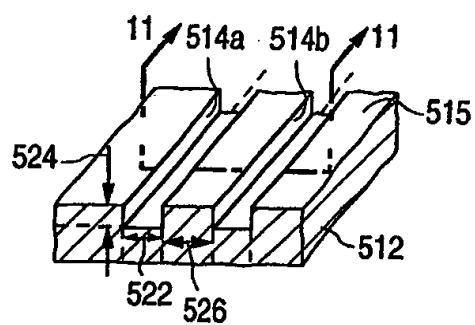
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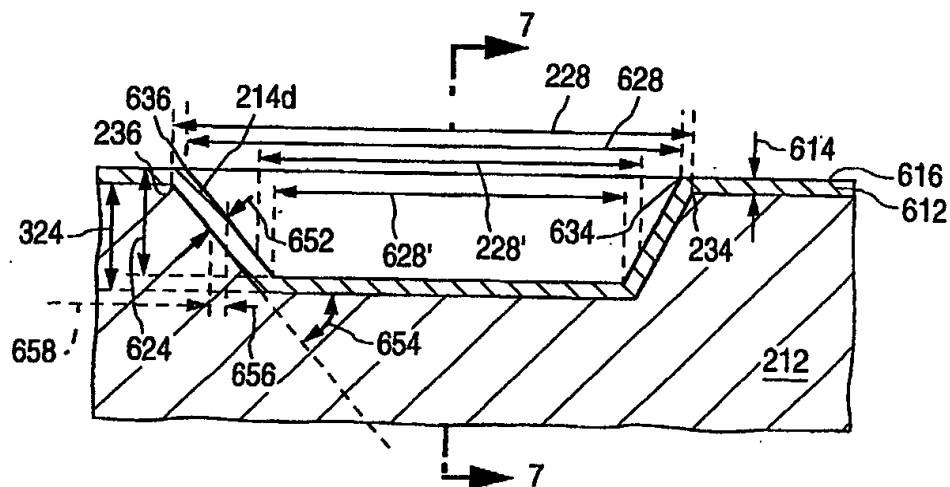
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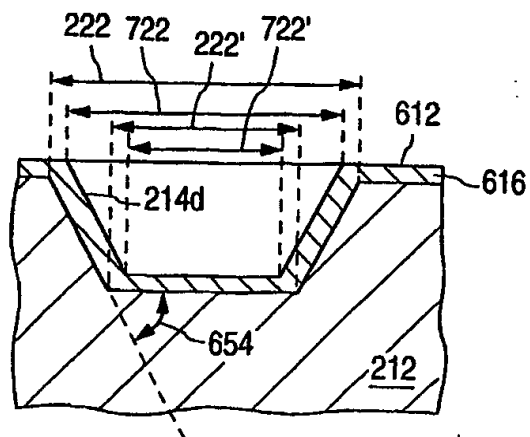
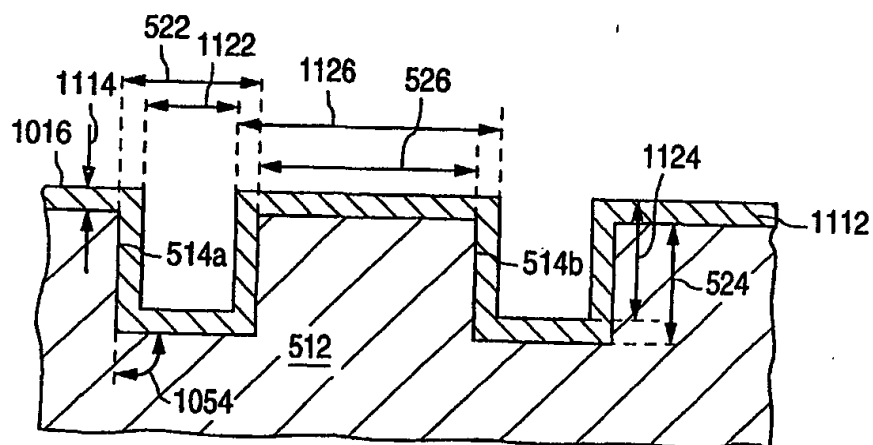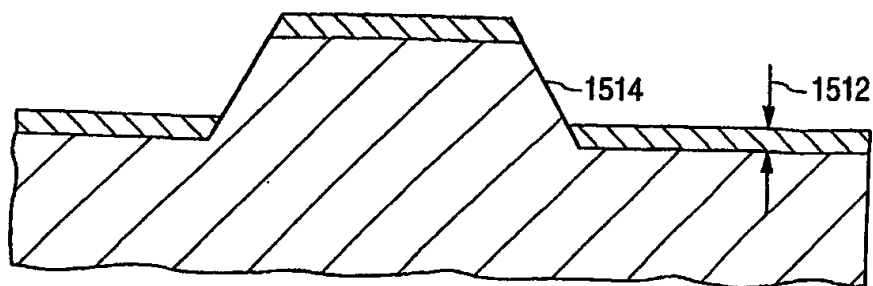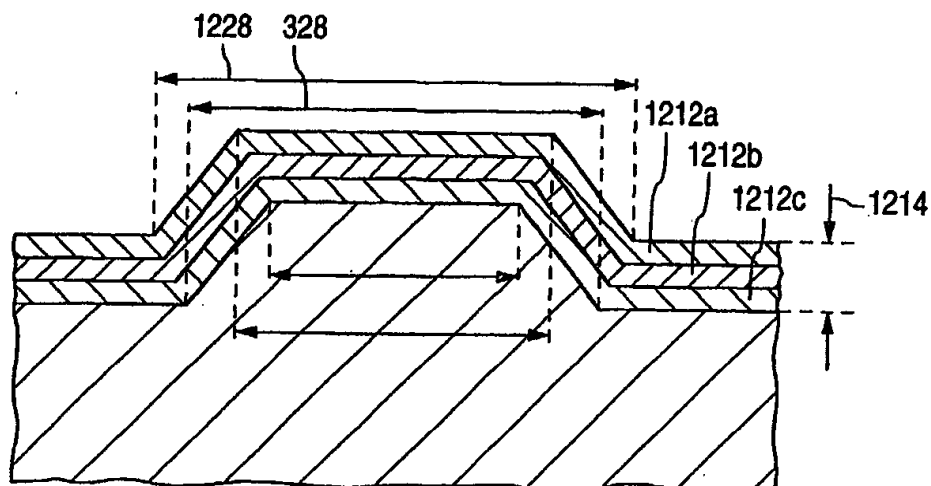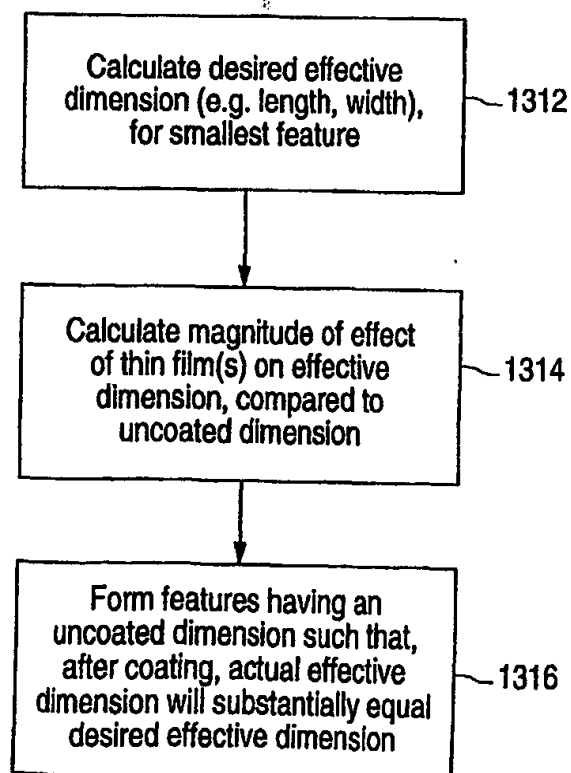**Fig. 7**

Fig. 8

Fig. 9

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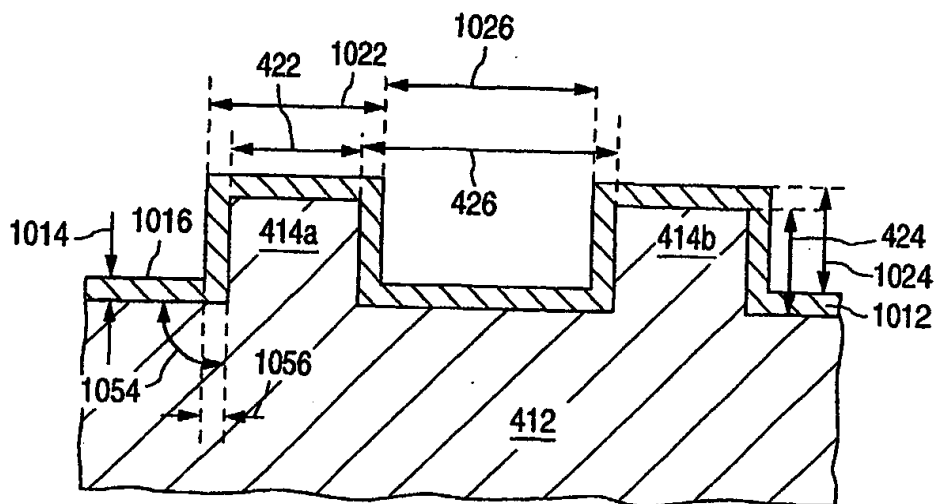
Fig. 10

Fig. 11

Fig. 15

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Fig. 12

Fig. 13

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Fig. 14C ⌐1428
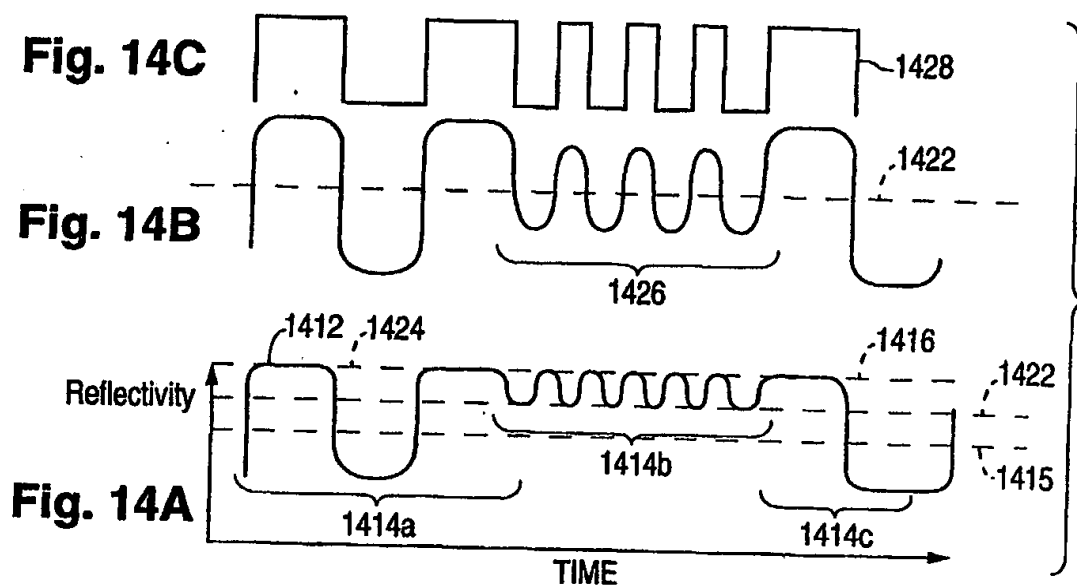
Fig. 14B ⌐1422

1426

1412 1424   1416
                                                    1422
Reflectivity

Fig. 14A
                                                    1415
1414a   1414b   1414c

TIME

RF
Analog 1614   1616   1612   1624   1626
        → Equalizer → Slicer → Phase
                                Measure → To
                                            DFLL

              DAC ← Integrator
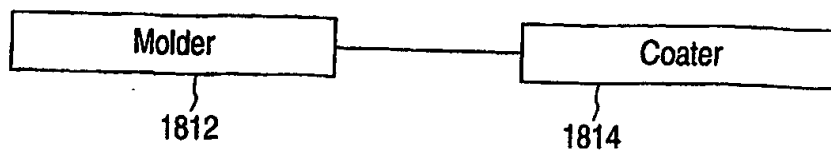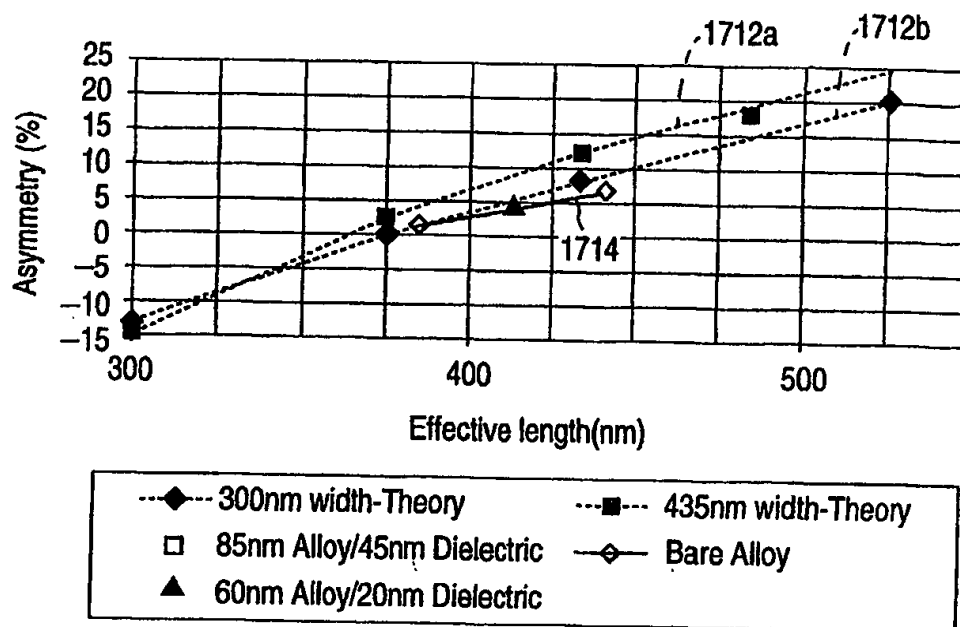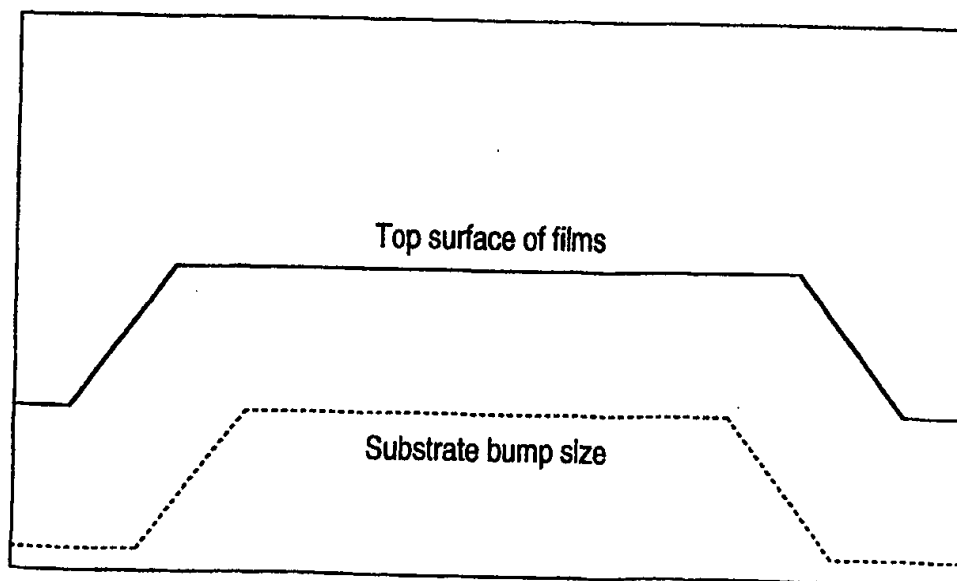
        1622   1618

Fig. 16

Molder ——————— Coater

1812   1814

Fig. 18

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Fig. 17A

Fig. 17B